The Summertime Build-up of Tropospheric Ozone Over the Middle East and North Africa as Observed by the TES Instrument

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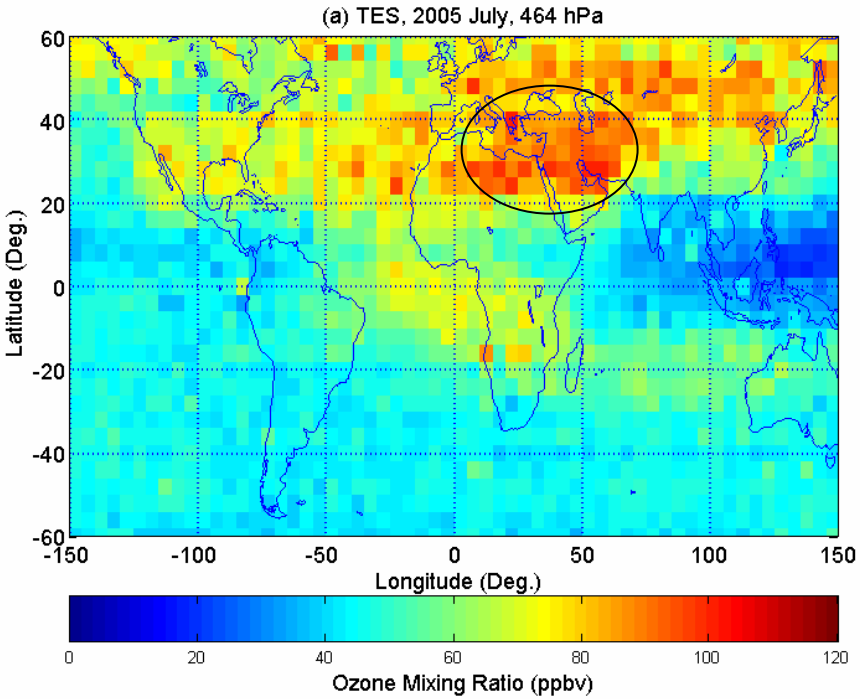
TES and GEOS-Chem

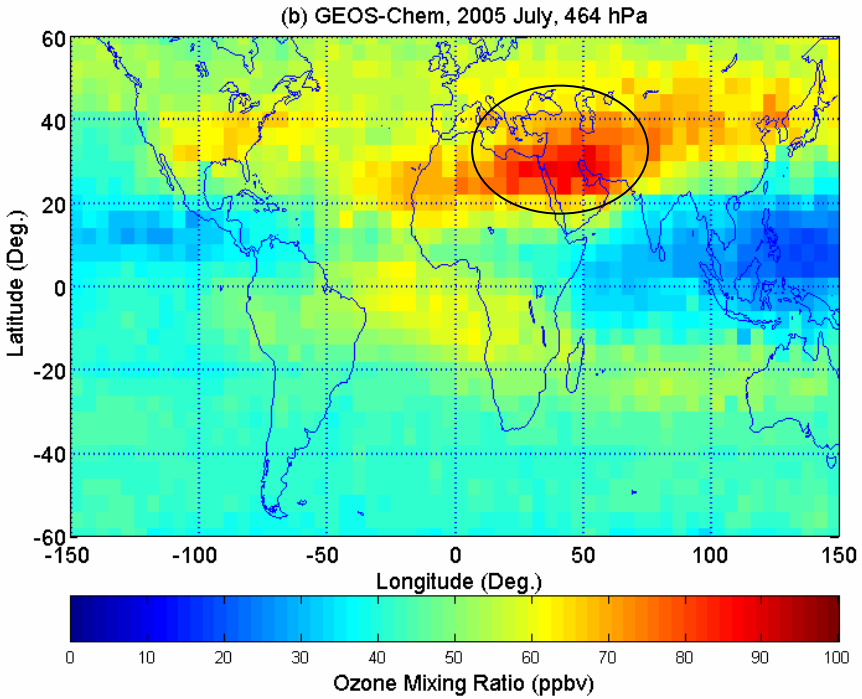
- TES
  - Ozone, CO, H_2O profiles in the troposphere and stratosphere (0-34 km)
    - Infrared Fourier transform spectrometer (3.3 - 15 μm)
    - Horizontal resolution: 5 x 8 km (nadir view)
    - 1-2 independent pieces of information vertically (in the troposphere)
- GEOS-Chem: A global chemical transport model
  - A Chemical Transport Model (CTM)
  - Driven by assimilated met. data from NASA/GMAO
  - Complete O_3-NO_x-HO_x-hydrocarbon chemistry
  - Horizontally, 4 by 5 degree
  - 55 vertical levels from the surface to 0.01 hPa, with ~18 in the troposphere

Ozone Enhancement: TES vs GEOS-Chem

TES, 2005/07, 464 hPa, ~6 km

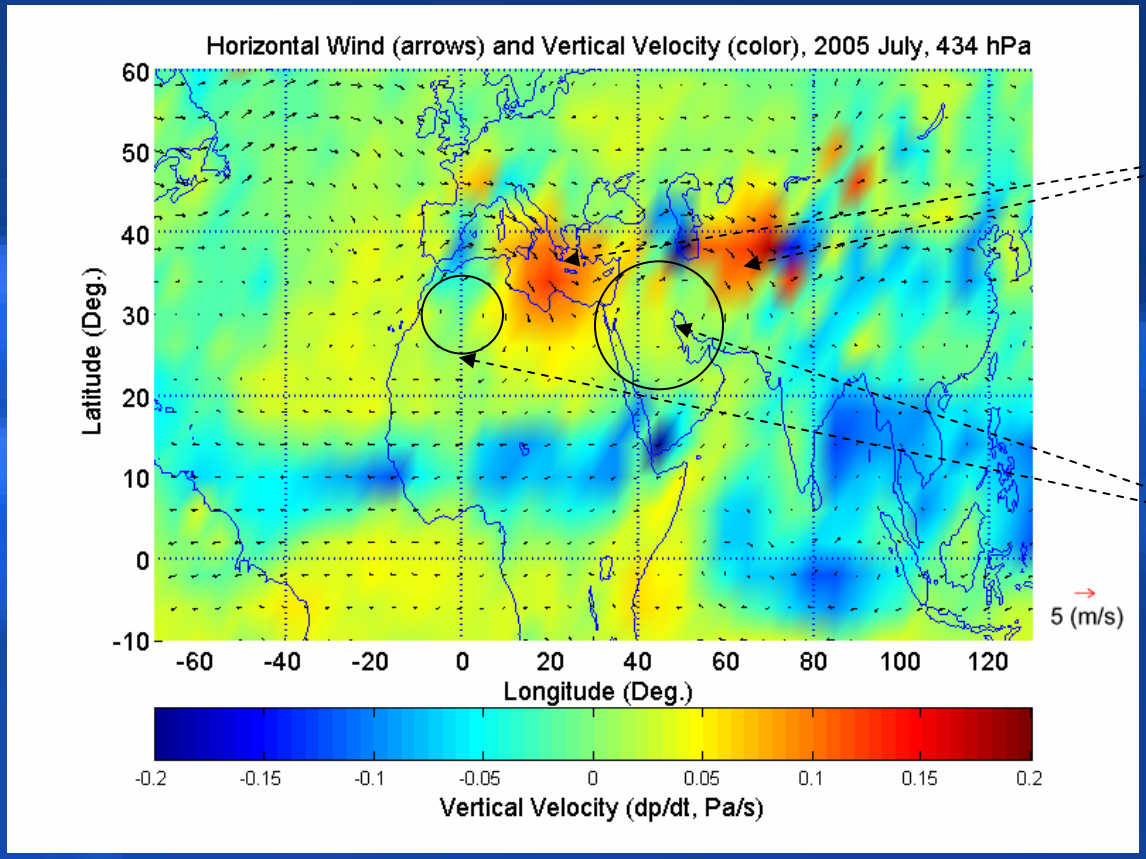


GEOS-Chem, 2005/07, 464 hPa, ~6 km



- The ozone enhancement across North Africa and the Middle East.
- Observed by TES during summer 2005-2007, but weaker in 2006.
- The spatial distribution of the ozone enhancement is similar in the model and the observations, but magnitude of the observation is larger.

Meteorological Conditions



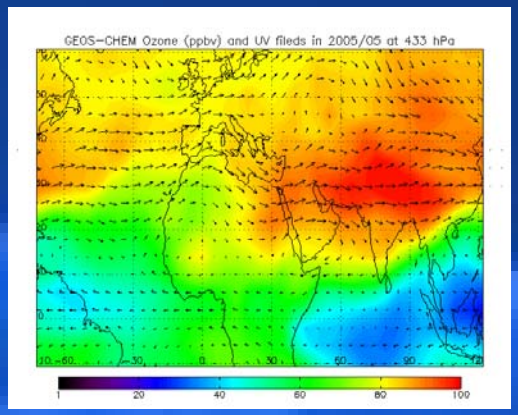
Strong descent

Anticyclones

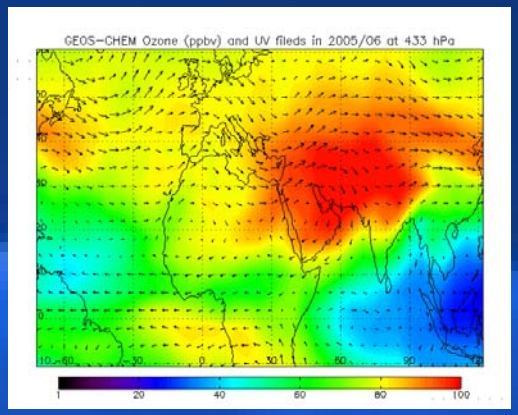
- Anticyclones are formed over northwestern Africa (over Atlas Mountains) and the Persian Gulf (near the Zagros Mountains)
- Associated with the Asian summer monsoon, there is strong descent over North Africa and Central Asia

Seasonal Variation of Circulation and Ozone

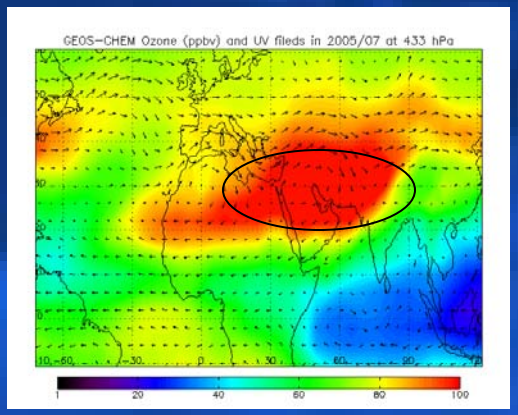
2005/05, 6-7 km, ~430 hPa



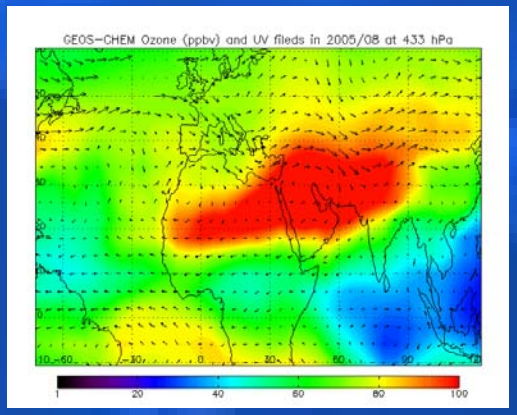
2005/06



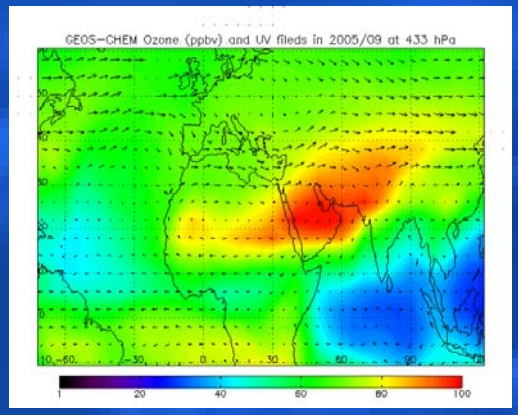
2005/07



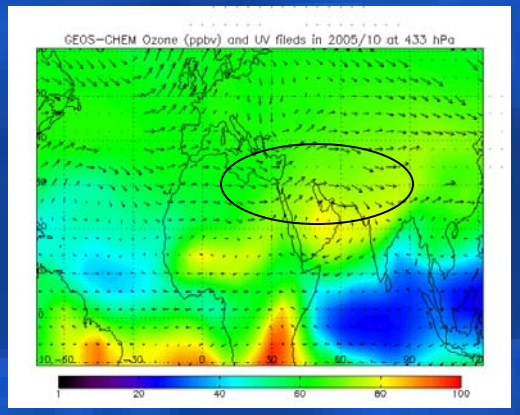
2005/08



2005/09



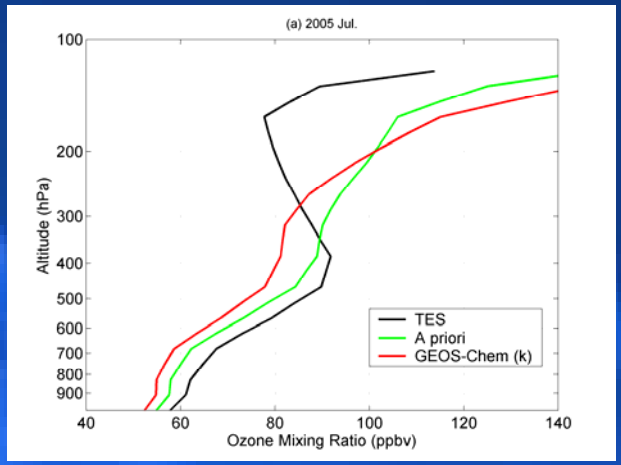
2005/10



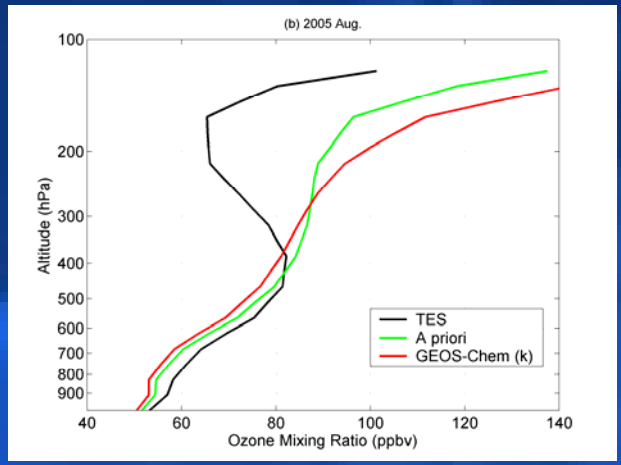
- Ozone accumulation in the Middle East is linked to trapping by the anticyclones in the middle troposphere
- After September, the anticyclones weaken and the region is more rapidly ventilated

Vertical Structure of Ozone over the Middle East

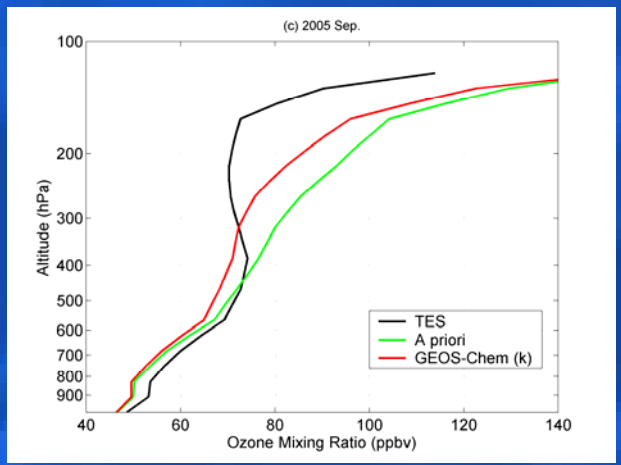
2005 July



2005 Aug.



2005 Sep.



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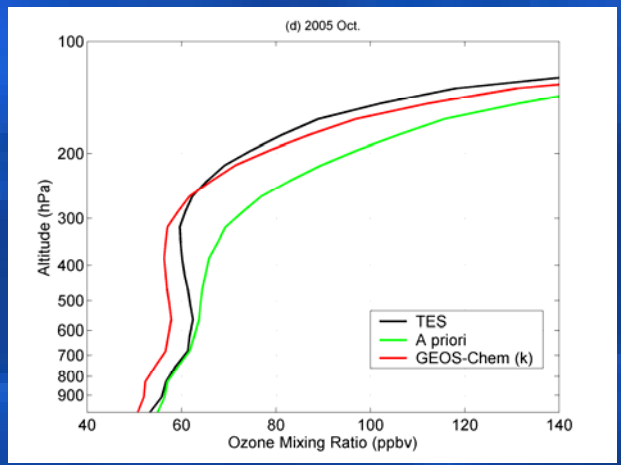
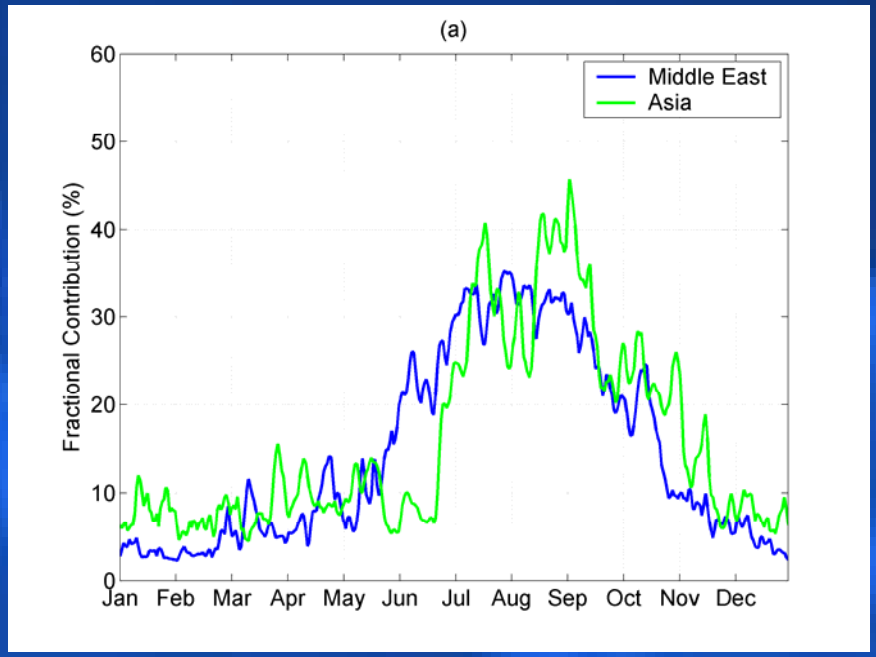


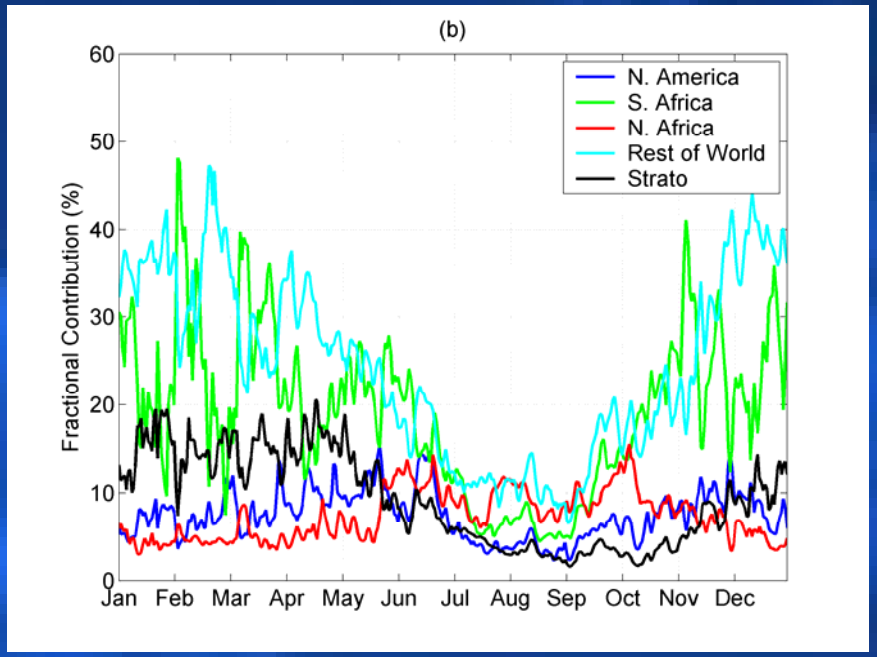
- Ozone buildup localized in the middle troposphere around 400 hPa in TES
- The peak in GEOS-Chem is less pronounced, suggesting excessive ozone in the upper troposphere in the model

Seasonality of Ozone Sources in the Middle East

Fraction contribution from Asia and the Middle East

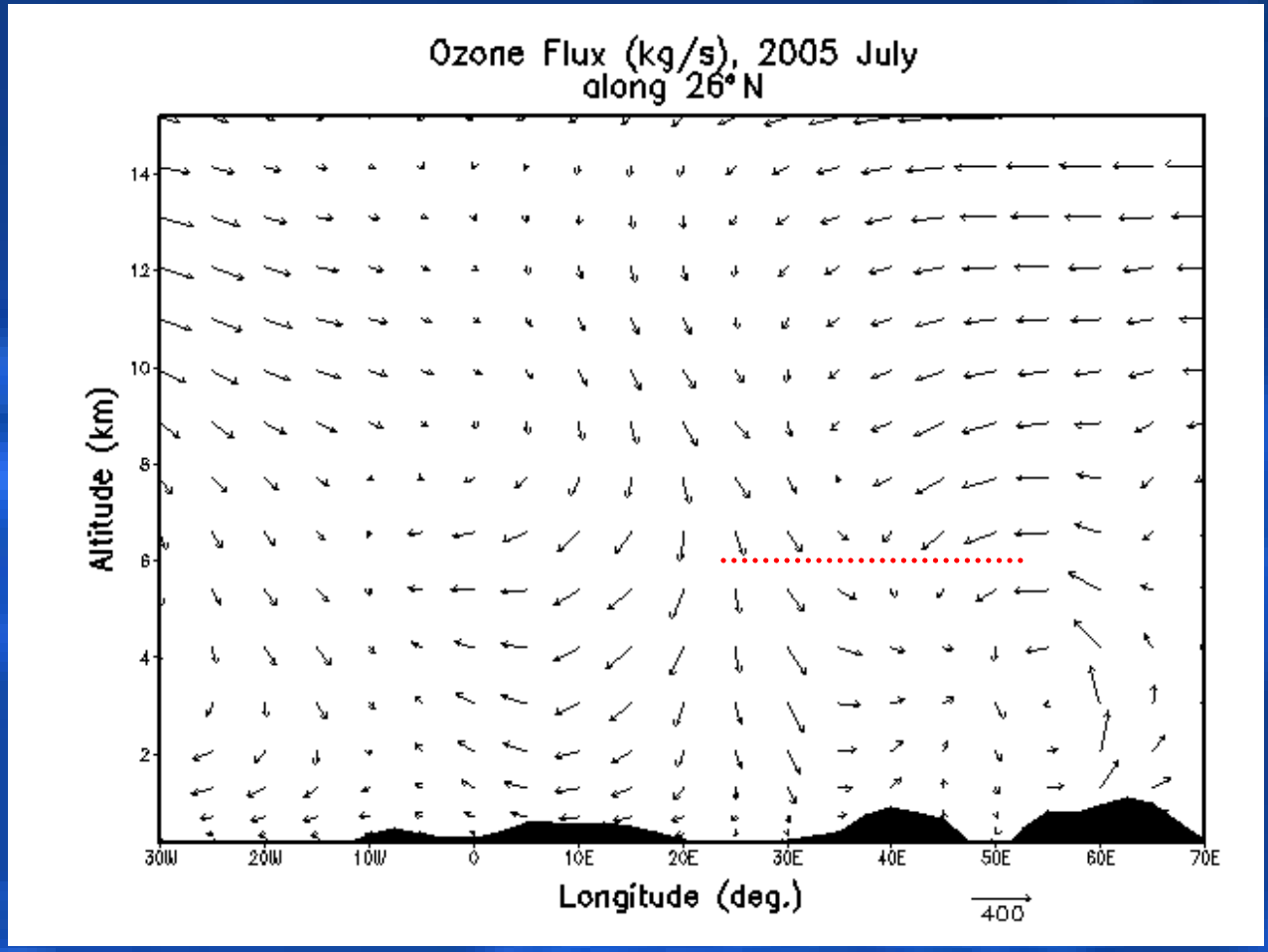


Fraction contribution from other sources



- Over the Middle East, local production and transported from Asia are major sources of ozone in summer time, each provides comparable contributions of 30-35% to the ozone buildup.
- The contribution of ozone from other sources is at a minimum in summer, reflecting the isolation of the region.

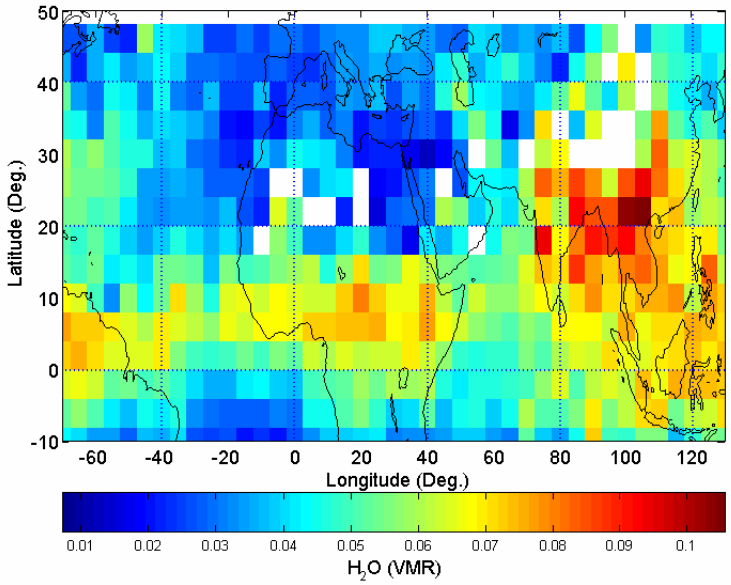
Ozone Fluxes along 26 deg.N, July 2005



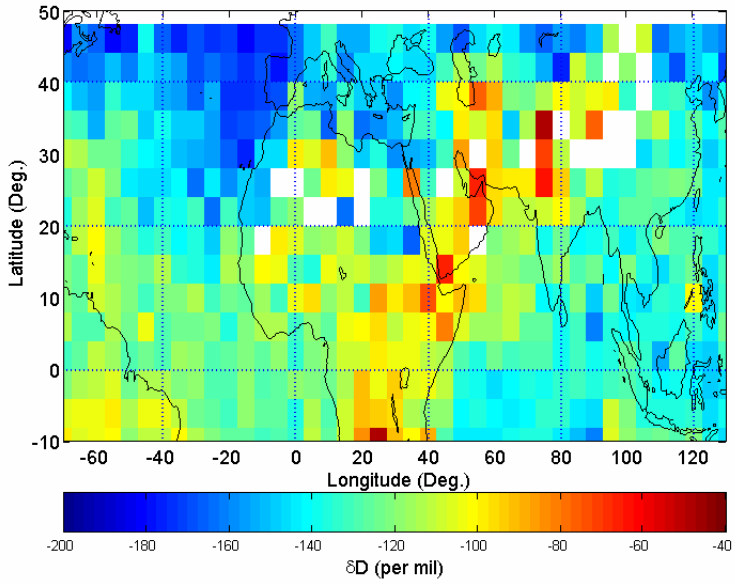
- Easterly transport from the Asian Monsoon outflow in the upper troposphere
- Strong downward transport of ozone over northeast Africa
- Upward transport of BL ozone over the Zagros Mountains (in Iran) and the Asir and Hijaz Mountains (in Saudi Arabia)

Constraints on the Transport Pathways from TES H_2O and HDO Measurements

Water Vapour, 2005 July, 850-450 hPa



HDO/H2O, 2005 July, 850-450 hPa



- Isotopic enrichment (high δD) over the Middle East and central Asia suggests that the air over these regions is more fresh, indicating influence of transport from the surface

Conclusions

- TES observation provides new evidence on the summer time ozone enhancement over the Middle East and North Africa, confirming the previously predicted summertime "Middle East ozone maximum."
- The accumulation of ozone in the region is strongly related to the dynamical isolation of the region, associated with the anticyclones over North Africa and the Middle East.
- Long-range transport from Asia and local chemical production are main causes to the formation of the ozone enhancement, each contributing 30-35% to the ozone build-up.
- Transport of surface pollution to the middle troposphere due to orographic lifting over Iran and the Arabian Peninsula provides a considerable source of ozone. Transport from the boundary layer accounts for about 25% of the local Middle Eastern contribution.

Thank you